



## Deformation in sand until failure

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**DEPARTMENT OF CIVIL ENGINEERING**  
AALBORG UNIVERSITY

# **Deformation in sand until failure**

**Benjamin Nordahl Nielsen**  
**Søren Dam Nielsen**



Aalborg University  
Department of Civil Engineering  
Section for building and infrastructure

**DCE Lecture Notes No. 61**

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by

Benjamin Nordahl Nielsen  
Søren Dam Nielsen

2019

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## Preface

This guide deals with measurements of deformations – in sand – until failure in a laboratory test to illustrate frictions angles part 1.

This guide is a part of a series, which explain the execution of geotechnical classifications experiments as carried out at the Geotechnical Engineering Laboratory at Aalborg University.

The guide is constructed as follows:

- *Appertaining standards*
- *Definitions*
- *Apparatus*
- Equipment calibration
- *Preparing the test sample*
- *Procedure for experiment*
- *Calculations*
- *Reporting*
- *Remarks*
- *Schema for experiment execution*
- *Appendix, if any*

It is recommended that the user of this guide reads the entire guide before the experiment is started.

Numbering of figures in the text is indicated by { }.

Units are indicated by [ ], e.g. [%].



## Definitions

The experiment is conducted in order to determine friction angles in the sand material. The experiment, consist of a sample shaping, a deformation phase and a failure phase.

The experiment must be conducted at various loads, e.g. 10 kg, 20 kg, 30 kg, 40 kg and 50 kg for both loose and dense condition.

## Apparatus

Apparatus list, numbers refer to figure 1 and 2.

- Simple failure appartus with lever and dial gauge {1}
- Control panel with vacuum pump {2}
- Weights
- Special vacuum cleaner with nozzle fitting the centring at disembedding {3}
- Scale, weight accuracy 0,1 g
- Bowls in corrosion resistant material
- Funnel {4}
- Centring with collection basin {5 }
- Mid-pieces for solid bedding {6}
- Sieves at 1 and 2 mm, respectively {7}
- Brush {8}
- Ruler {9}
- Membrane (length of membrane 150 mm) {10}
- Sand mould {11}
- Pressure heads {12}



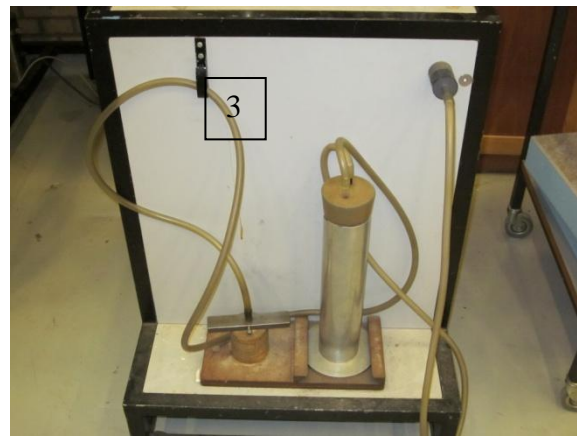


Figure 1: Simple failure apparatus with control panel plus special vacuum cleaner.

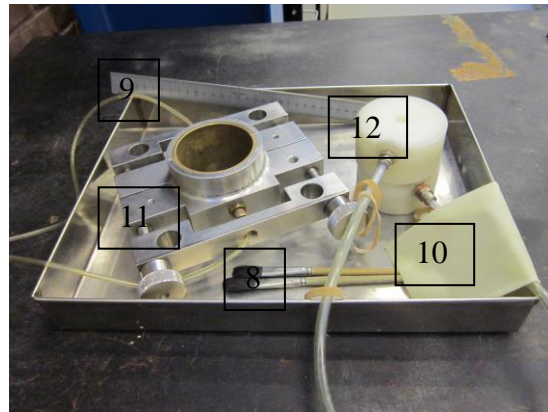
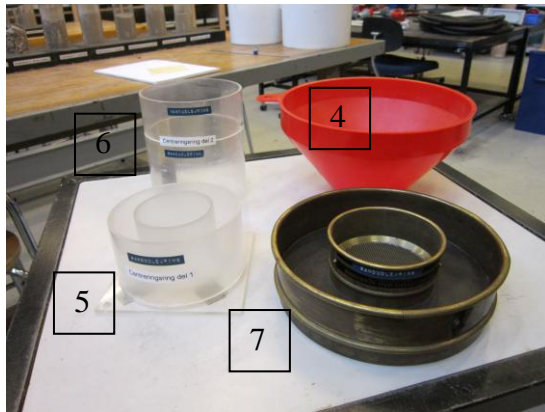


Figure 2: Apparatus for sample shaping plus sand mould and pressure heads.

## Equipment calibration

The apparatus used in the experiment do not require calibration. However, before each experiment the maximum pressure kPa is read on the vacuum pump. The membrane must be checked for leakages.

## Preparing the test sample

Prior to the experiment, a suitable sample size (approx. 2.0 kg) is dried at 105°C to a steady weight. If Baskarp sand is used, the sand is not dried prior to the experiment.

## Procedure for the experiment

- The vacuum pump is started. The vacuum pump is placed under the trolley.
- Figure 3 shows a picture of the control panel. This test do not use "Sample 2" at the control panel.

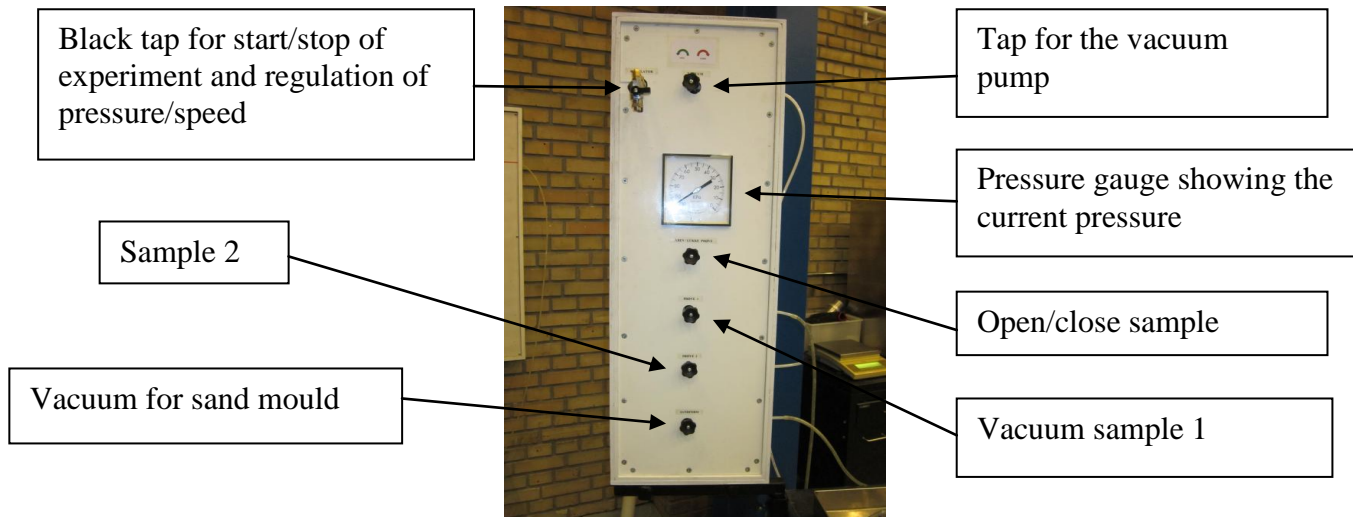


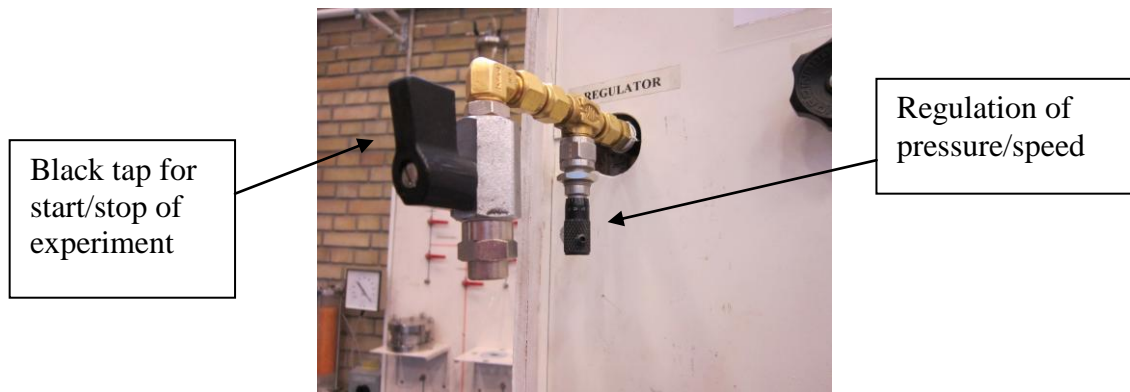
Figure 3: Control panel prior to experiment. All taps are closed.

- When the experiment starts all taps should be in closed position, except from "Open/close sample", and the vacuum pump should be started, figure 4.



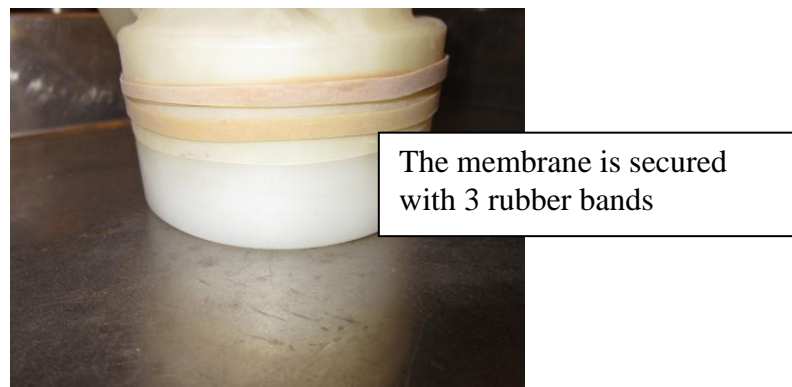
Figure 4: Open/close position.

- The regulation of pressure opens and testes. The pressure remains open. This is done by turning the black tap, figure 5.



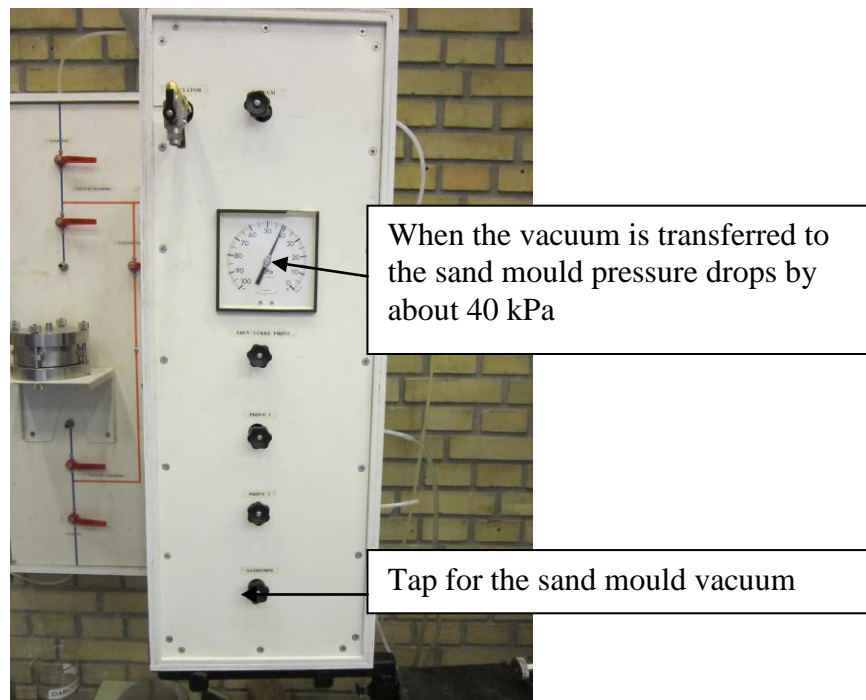
**Figure 5: Black tap for starting the experiment and regulation of pressure/speed.**

- A suitable sample size is weighed (approx. 2.0 kg) and noted in the schema.
- Lower pressure head is placed on a tray with the filter stone upward and the membrane is placed on the pressure head. The membrane is secured with 3 rubber bands on top of each other outside of the membrane. There must not be any wrinkles on the membrane, figure 6.

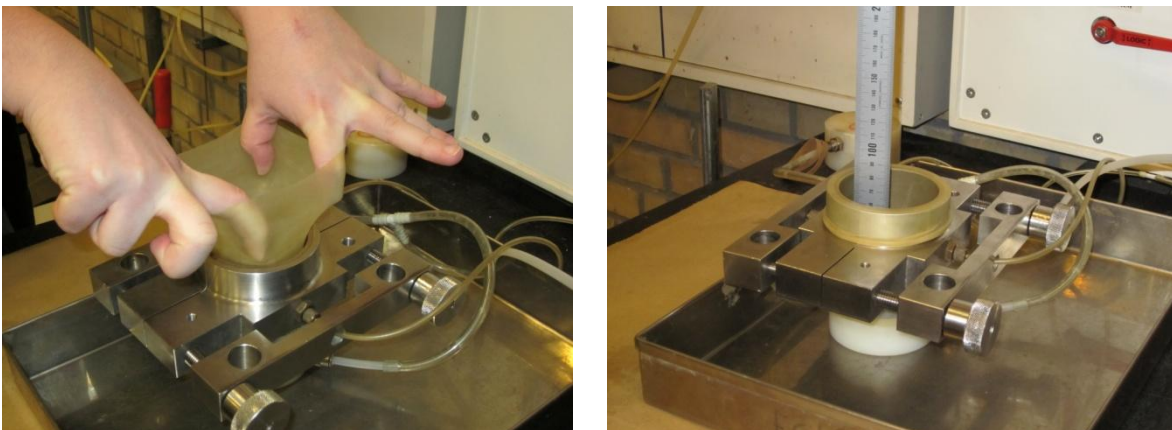


**Figure 6: Membrane on the lower pressure head.**

- The sand mould is placed gently on the lower pressure head and the membrane is pulled up through the sand mould (be careful not to make a hole in the membrane), figure 6.
- The vacuum is opened on the sand mould and the membrane is pulled up over the rim of the sand mould. The membrane is pulled up at the same time it is heeled over the sand mould. There should not be any wrinkles on the membrane, figure 8.
- The inner height and diameter of the sample is measured, figure 8.



**Figure 7: Vacuum on the sand mould.**



**Figure 8: The membrane in the sand mould and measurement of the height and diameter of the sample.**

### **Set-up of loose condition:**

- The sample is embedded as loose condition. This is done by placing the centring ring marked "centreringsring del 1" in top of the sand mould and then the sieves in the top. Then the sand is poured in the funnel so the sand runs through the sieves and down into the centring ring before it gets into the membrane. The sand is put into the funnel by pouring it with a smooth motion from side to side in the funnel, figure 7.



**Figure 9: Set-up of loose condition.**

### **Set-up of dense condition:**

The sample is embedded as dense condition. This is done by putting the mid-pieces between the centring and sieves so the drop is increased, figure 11.



**Figure 10: Set-up of dense condition.**





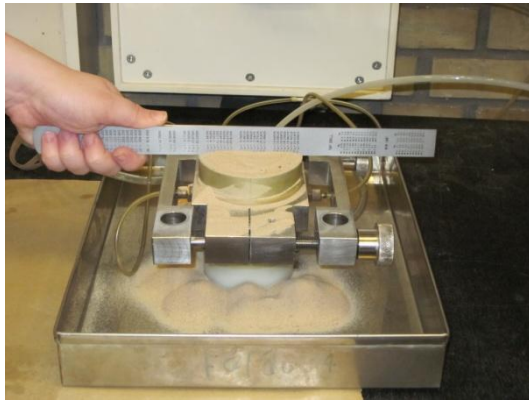
**Figure 11: Embedding of sample.**

- The funnel is removed (brushed clean into the sieves) and excess material is vacuumed with the special vacuum cleaner in the inner ring of the centring (before the vacuum cleaner is turned on, check to see if it has been emptied of material), figure 12.
- The vacuum cleaner bin is emptied for sand, and the sand is poured into the original bowl.
- The centring ring is removed and excess material is put back into the original bowl.



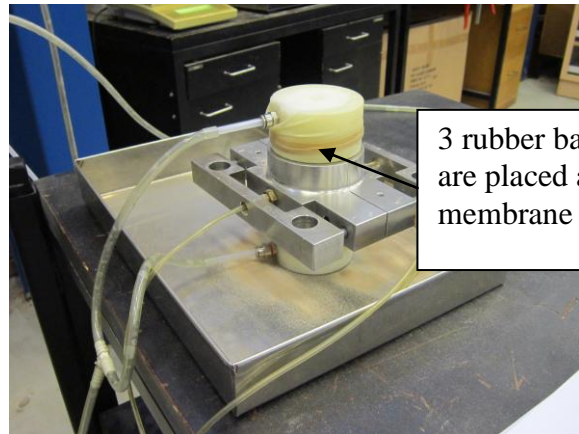
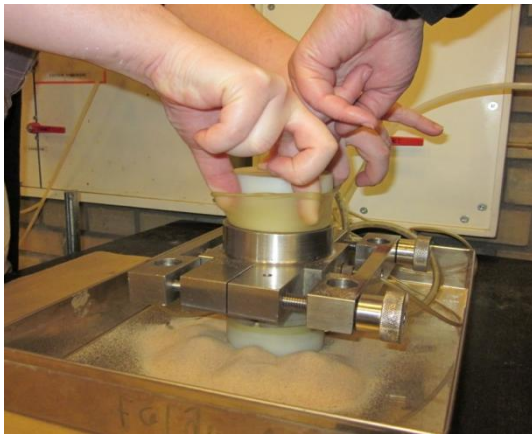
**Figure 12: Vacuuming excess material.**

- The sample surface is levelled. This is done with a steel ruler along the top side of the sand mould as the ruler is moved from the middle and toward the sides, see figure 13.
- The sample and sand mould is brushed clean. If necessary, the horizontal part of the membrane is brushed clean with a finger so as not to disturb the sample, figure 13.



**Figure 13: Levelling the sample and cleaning the membrane.**

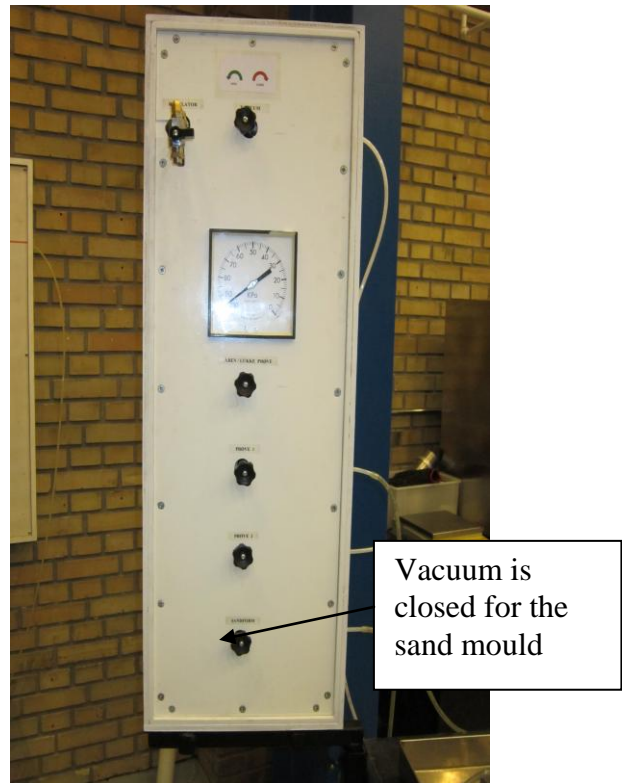
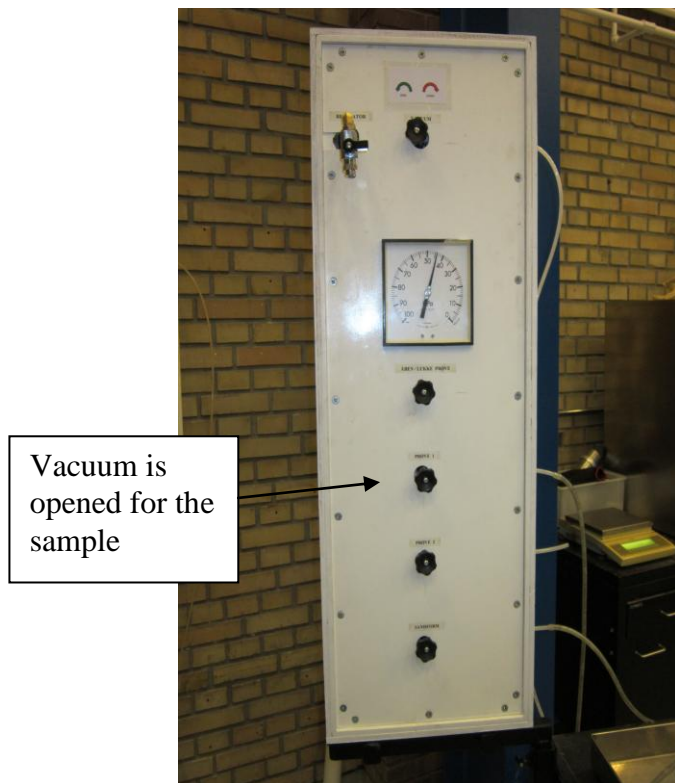
- The upper pressure head with the filter stones downwards is placed on the sample, and the membrane is pulled up over the pressure head and secured with 3 rubber bands. There should not be any wrinkles on the membrane. The rubber bands are placed on top of each other, figure 14.



3 rubber bands  
are placed at the  
membrane

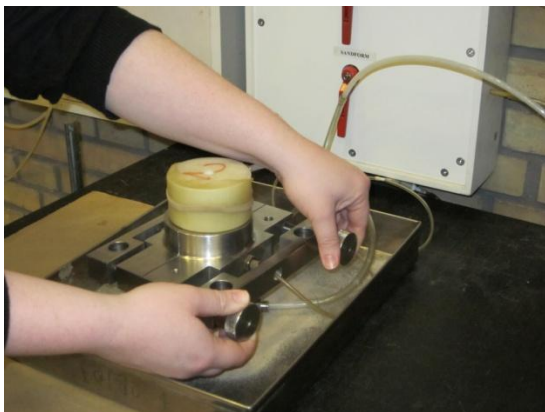
**Figure 14: Upper pressure head is placed.**

- Vacuum is opened for the sample (sample 1), figure 15.
- Vacuum for the sand mould is closed, figure 15.



**Figure 15: Vacuum is opened for sample, and vacuum is closed for sand mould.**

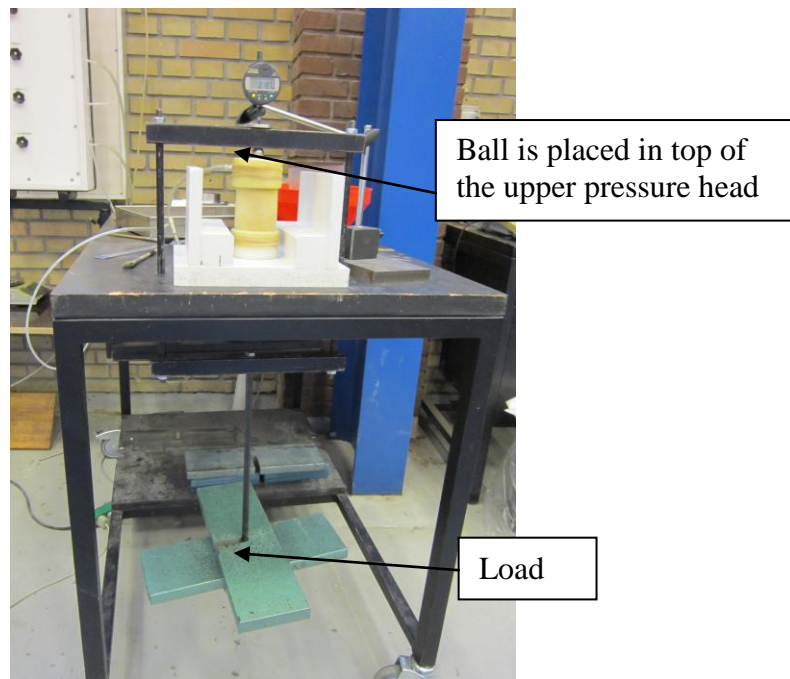
- The sand mould is removed. This is done by loosening the screws (left hand's thread = screw to the right). Brush clear of sand. The sand is put back in the original bowl and weighted, figure 16.



**Figure 16: Sand mould is removed and sample is brushed clean.**

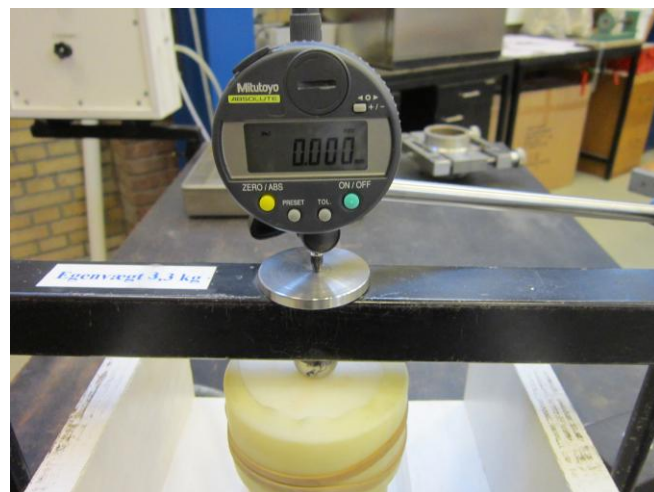
- The sample is centred in the apparatus, figure 17.
- The pre-determined weight is put on the lever, figure 17.





**Figure 17: Sample is centred in the apparatus and weights are put on.**

- Check whether the controllers for the pressure are completely closed, figure 3.
- The dial gauge is centred and set to 0.000 on digital dial gauge and the vacuum is shut off on the control panel, figure 18 and 19.



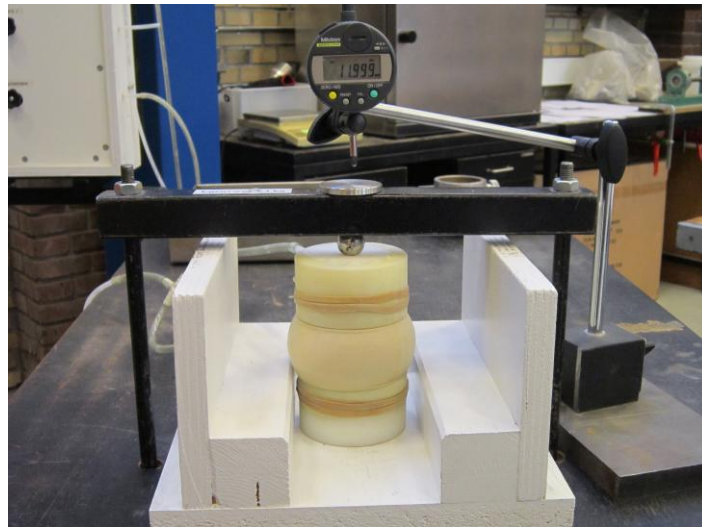
**Figure 18: Sample is centred in the apparatus.**

- The vacuum pump is shut off.



**Figure 19: Vacuum pump is shut off on the control panel during the experiment.**

- Note down the pressure from the control panel and mm from the dial gauge at pressure  $\sim 100$  kPa, figure 20.
- At the start of the experiment, the pressure will be at maximum pressure. The pressure is reduced with 5 kPa to approx. 70 - 60 kPa, and the reading on the dial gauge is noted down. This is done with each reduction. The reduction and the pressure must be done "smoothly", figure 20.
- From approx. 70 - 60 kPa to approx. 50 - 40 kPa, the pressure is reduced by 2 kPa and the reading on the dial gauge is noted down. This is done with each reduction.
- From approx. 50 - 40 kPa until rupture, the pressure is reduced by 1 kPa and the reading on the dial gauge is noted down. This is done with each reduction, figure 21.



**Figure 20: Sample after break.**

The table below is guiding and indicates how the pressure must be reduced at various loads for Baskarp sand in loose condition.

	Weight = 10 kg	Weight = 20 kg	Weight = 30 kg	Weight = 40 kg	Weight = 50 kg
Pressure reduced by 5	100 - 60	100 - 60	100 - 60	100 - 70	100 - 70
Pressure reduced by 2	60 - 40	60 - 40	60 - 40	70 - 50	70 - 60
Pressure reduced by 1	40 - failure	40 - failure	40 - failure	50 - failure	50 - failure

The table below is guiding and indicates how pressure is reduced at various loads for Baskarp sand in dense condition.

	Weight = 10 kg	Weight = 20 kg	Weight = 30 kg	Weight = 40 kg	Weight = 50 kg
Pressure reduced by 5	100 - 60	100 - 60	100 - 70	100 - 70	100 - 70
Pressure reduced by 2	60 - 40	60 - 40	70 - 50	70 - 50	70 - 50
Pressure reduced by 1	40 - failure	40 - failure	50 - failure	50 - failure	50 - failure

- The sample is extracted from the apparatus after completion of experiment, and the amount of material is weighted in a separate bowl (as control weighting). The inside of the membrane as well as the pressure heads are brushed clean for sand, figure 21.



**Figure 191: The membrane is cleaned after the experiment.**

## Reporting

The settling on the dial gauge is read with 3 decimals.

## Remarks

It is important that you do not touch the table or the weights during the actual execution of the experiment as it can affect the deformations and when failure occurs.

By a constant weight, it is understood that the sample weight does not change more than 0.1% from the original weight of the sample after additional four hours

## Page 1/1

Case			Case no.
Examined on	To	Lab. no.	Boring nr.
Controlled	Approved	Level	Appendix no.

### Simple failure experiment to illustrate friction angles in sand

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